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EVALUATION OF A SYSTEM FOR TRACKING PATIENTS AT FORWARD MEDICAL TREATMENT FACILITIES

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SUMMARY

Problem

Rapid and accurate collection, maintenance, and transfer of combat casualty information is necessary for effective medical management of the individual casualty, medical regulating, and theater evacuation policy. The current method of maintaining this flow of information at forward Medical Treatment Facilities (MTFs) relies primarily upon patient tracking information manually supplied to the facility's Medical Operations Center (MOC) from each of the functional areas of the treatment facility. This approach to patient tracking, however, is manpower intensive, relies upon highly trained medical personnel to be administrators, and detracts from the ability of the facility to deliver the highest possible level of casualty care.

Objective

The primary objective of the current study was to assess the relative performance of manual and automated patient tracking systems at a Collecting and Clearing (C&C) company.

Approach

A prototype automated system, named MEDTRAK, was developed and tested in a simulated C&C during combat training exercises. A network was assembled at the C&C consisting of three touchscreen Personal Computers (PCs), and four laptop PCs equipped with short-range Radio Frequency (RF) communication modems and the MEDTRAK system software. At 10-minute intervals throughout the duration of the exercise, the observed location of each patient within the facility was recorded and compared to logs compiled by the manual system and the MEDTRAK system.

Results

The patient tracking effectiveness of the current manual system and the MEDTRAK system, determined by comparing the observed patient location to the system logs, showed that the MEDTRAK system recorded significantly fewer errors than did the manual system. Moreover, the majority of the errors that did occur were less detrimental to the operation of the MTF than those recorded by the manual system.

Conclusions

The MEDTRAK system demonstrated that automation of the patient tracking function at forward MTFs dramatically improved the effectiveness of patient accounting procedures. Both personnel requirements and patient tracking errors were substantially reduced because the MEDTRAK system provided automatic patient admission procedures and replaced manual telephone and runner communications with automated RF system communications.

INTRODUCTION

The health services support system comprises five echelons of care ranging from first aid and emergency medical care rendered at echelon 1, to convalescent, restorative, and rehabilitative care rendered at echelon 5. Within the Fleet Marine Force (FMF), the medical battalion plans and supervises establishment of appropriately sized Medical Treatment Facilities (MTFs) (Fleet Marine Force Manual [FMFM] 4-51, pp. 1-2, 1-3, 1-5). At the first echelon, unit hospital corpsmen provide first aid in the field, and a highly mobile Battalion Aid Station (BAS) is established in a relatively safe environment. At the second echelon, two platforms are used: a Collecting and Clearing (C&C) company and a Surgical Support Company. These units are responsible for establishing and maintaining treatment facilities for surgery, receiving and treating casualties evacuated from BASs, and providing temporary hospitalization to casualties (FMFM 4-50).

The operation of these facilities requires rapid and accurate collection, maintenance, and transfer of combat casualty information for effective medical management of the individual casualty, medical regulating, and theater evacuation policy (MAF ORDER P6320.1A). A patient affairs office or a Medical Operations Center (MOC) typically functions as the administrative center of the medical company. Each functional area within the medical company (e.g., triage, x-ray, wards) is equipped with field phones to facilitate communication with the MOC. Field radios, also located at the MOC, serve interechelon communication requirements (Congleton et al., 1986).

Because these MTFs are designed for short-term casualty care, incoming patients create a continuing need for the relatively rapid evacuation of those occupying beds to higher echelons. The pulse and pause nature of the incoming casualty stream compels these facilities to monitor and maintain the orderly flow of casualties through the system at all times to remain effective in carrying out their medical mission. Effective management of the casualty stream is dependent upon the efficient and effective flow of patient data in support of casualty evacuation; blood products management; clinical services, such as radiology, laboratory, and nursing; medical logistics; patient administration; and command and control (Task Force Medical Regulating Manual, 1990).

The current method of maintaining this flow of information at the medical company relies primarily upon information manually supplied to the MOC from each of the functional areas within the facility. Through continuous monitoring of each individual area, MOC maintains status boards and executes decisions regarding patient flow, bed status and availability, operating room backlog, medical regulating, and blood management. This approach to patient tracking, however, is manpower intensive. It results in highly trained medical personnel acting as administrators and detracts from the ability of the facility to deliver the highest possible level of casualty care. Failure to execute adequately this function at the medical company level, in turn, reduces the effectiveness of medical regulating and the

discharge of theater evacuation policy because accurate and timely casualty data may not be available as input to the decision making process (Congleton et al., 1986).

Inefficient patient tracking procedures cannot be addressed by assigning additional personnel or material to the task. A 1988 reorganization of medical battalion administration mandates no increase in staffing levels beyond those currently in place (FMFM 4-50). Consequently, an automated patient tracking prototype for medical company treatment facilities was proposed. This prototype, named MEDTRAK, was designed to provide a method of assembling and monitoring casualty tracking data in support of time-sensitive decisions critical to the success of the medical mission.

MEDTRAK Model

The proposed patient tracking system (MEDTRAK) calls for placing hand-held, touchscreen personal computers (PCs) in all second echelon MTFs. These touchscreen PCs would be radio frequency (RF) equipped to maintain communication with a central processing PC. This central PC would automatically monitor a network of remote PCs assigned to patients upon admission to the MTF. In addition, the central PC would maintain the patient tracking function, assign patient treatment priorities, maintain the in-house patient medical database, communicate laboratory requests/results, and automatically generate status reports (i.e., patient records, bed status, blood inventory, and patient lists).

As casualties arrived at the MTF, they would be assigned one of the portable touchscreen computers, which would be used as their treatment record input device. Each of the remote PCs would incorporate a data exchange interface for a personal data carrier, such as the proposed Multi-technology Automated Reader Card (MARC) initiated by the Department of Defense Information Technology Policy Board (DoD[ITPB]). At triage, a personal data carrier, for example the casualty's MARC, would be downloaded to the PC. All biographical data, pre-existing medical conditions, such as allergies, and the casualty's field treatment record would then be automatically forwarded, via RF communication, to the central processing PC located in the MOC. Upon receipt of the communication, the MOC PC would automatically admit the casualty and assign him a patient number. An electronic medical treatment record would also be created for the casualty at this time. All subsequent medical data accumulated on the casualty would be stored in this record until time of discharge.

On the casualty's PC, care providers would be presented with the medical data input forms specific to each treatment area within the MTF. Each of the forms, which uses the touchscreen as the data input interface, would collect casualty medical data currently assembled with manual paper-and-pencil instruments.

As the casualty enters each successive treatment area within the MTF, care providers at the location would depress a single "electronic button" displayed on the casualty's PC screen, thereby initiating an RF transmission notifying the central PC that the casualty has

arrived. Once admitted to a location, the location specified on the casualty's PC should match the actual location of the casualty. If a match does not occur, the patient was either transferred to an unintended location or an error was made in the selection of the next location. Patients arriving at an unintended location will draw immediate attention and be re-directed to the correct destination. Similarly, location data input errors would be immediately corrected because the location displayed on the casualty's PC determines which medical data input forms are available for documentation. For example, if a casualty's PC identifies him as being in x-ray, then only x-ray related forms would be available to the care providers in that location. Once treatment has been rendered and the patient is ready for transfer to the next treatment area (e.g., operating room [OR]) care providers again depress a single "electronic button" displayed upon the casualty's PC, automatically initiating an RF communication notifying the MOC that the patient is in-transit to the next treatment area (i.e., OR). When the patient arrives at the next location, the process is repeated. At time of discharge, all accumulated medical data would be uploaded onto the patient's personal data carrier and an RF communication initiated, notifying MOC of the discharge. The casualty's PC would then be cleared in preparation for use with another patient.

To evaluate the effectiveness of the MEDTRAK concept in a combat environment, a simulation of the system was assembled and tested during mass casualty field medical training exercises at the Field Medical Service School (FMSS), Camp Pendleton, California. Limitations in hardware availability required that the system be evaluated using fewer PCs than proposed for a fully operational version of the system. To address these limitations, software modifications were incorporated into the MEDTRAK system, which allowed the reduced number of PCs to function as if they were part of a large multiunit network. The purpose of the present study was to conduct a side-by-side evaluation of the MEDTRAK system and the current paper-and-pencil method of patient tracking during a mass casualty training exercise.

METHOD

Sample

The 1st Medical Battalion, Camp Pendleton, California, operated the current manual system during the combat training exercise and seven NHRC research personnel maintained the MEDTRAK system. The simulated patients were 20 Navy corpsmen, undergoing Fleet Marine Force training at the FMSS, Camp Pendleton, California. The FMSS was selected to provide the setting for the study because of the structure of its training program. The school conducts an intensive 6-week training program designed to prepare corpsmen for a combat support role. Two of these weeks are devoted to field exercises in which the students practice implementing their medical and tactical skills in a simulated combat environment.

Field Conditions

The field exercises are designed to provide training in the medical and tactical requirements of the first two echelons of care. During these exercises, platoons of corpsmen advance up one of two canyons that are arranged to provide a series of hostile enemy encounters. Following each engagement, the corpsmen provide simulated treatment and then evacuate "casualties" to a BAS set up at the base of the canyons. At the BAS casualties are reassessed and administered additional treatment. "Casualties" who are unable to return to duty following treatment are evacuated to a simulated C&C located in a relatively secure location outside the combat area. The data for the present study were collected at this simulated C&C.

MEDTRAK Evaluation Model

A network was assembled at the simulated C&C consisting of three touchscreen PCs, and four laptop PCs equipped with short-range RF communication modems. One laptop PC was placed in the MOC to monitor the network and maintain the patient tracking and status board functions. One of each of the six remaining PCs was placed in the patient treatment areas, including triage, Admitting and Sorting (A&S), x-ray, OR, General recovery ward (G-Ward), and Intensive care ward (I-Ward).

Each of the computers positioned in the individual treatment areas was equipped with the MEDTRAK patient tracking software. This system provided the capability to select from a list of current C&C patients, call up the patient record, and enter the relevant medical data applicable to the treatment area. Figures 1-3 present examples of PC screens illustrating these capabilities. In Figure 1, the PC screen used to display the list of patients currently in the facility is shown as it appeared to system users. Figure 2 shows an example of a patient record screen, in this case, the medical treatment record for fictitious patient number 23, Pat Spanos. In Figure 3 an example of one of the medical data input screens is shown. This illustration represents one of the triage data collection forms used to record medical data on fictitious patient number 18, Tony Johnson. To record data, care providers depressed touch sensitive areas on the screen pertaining to the items they wished to record. Each time a patient was received into a location or transferred to the next location, the attending medical care provider depressed an electronic "patient transfer" button or an electronic "patient receive" button displayed on the patient's PC. This action automatically initiated an RF communication to the MOC updating the location of the patient.

The 386 laptop maintaining the patient tracking and status board functions in the MOC was also equipped with the MEDTRAK software. The software provided MOC personnel with an electronic map of the MTF, which designated and actively tracked the location of each patient within the facility by his patient number. Figure 4 shows an illustration of the screen used by MOC personnel to track and maintain patient location information. MEDTRAK also provided options for generating lists of the patients within the facility either by name or patient number and the cumulative medical data collected on each of them from the time of

FACILITY PATIENT LIST

ID	SSN	LOCATION	PATIENT
001	000-00-0000	A - WARD	LARSON, TIMOTHY P
002	000-00-0000	DISCHARGED	MURPHY, MARYANN R
003	000-00-0000	DISCHARGED	NEWBURGH, ERIC M
004	000-00-0000	I - WARD	PETERSON, JOHN G
005	000-00-0000	DISCHARGED	SMITH, DAVID J
006	000-00-0000	G - WARD	BECKMAN, GERALD K
007	000-00-0000	I - WARD	KENNEDY, JEROME P
008	000-00-0000	G - WARD	WILLIAMS, SUSAN A
009	000-00-0000	MORGUE	CAMPBELL, STEVEN M
010	000-00-0000	G - WARD	0'NEILL, VICTOR H
011	000-00-0000	PRE - OP	MASTERS, PAUL S
012	000-00-0000	G - WARD	HAMILTON, GARY H
013	000-00-0000	OR - 1	JACKSON, KELLY R
014	000-00-0000	G - WARD	FREDRICKSON, JEFFREY F
015	000-00-0000	PRE - OP	AUSTERMANN, LAWRENCE P
016	000-00-0000	A & S	WILKINS, ROBERT J
017	000-00-0000	A & S	MASSENBURG, JEAN G
018	000-00-0000	TRIAGE	JOHNSON, TONY D
019	000-00-0000	IN - TRANSIT	LINDFIELD, CRAIG K
020	000-00-0000	TRIAGE	BRADSHAW, DANIEL, S
021	000-00-0000	TRIAGE	HINCKLEY, MICHAEL D
022	000-00-0000	IN - TRANSIT	GRANT, HOWARD T
023	000-00-0000	A & S	SPANOS, PAT L

SELECT LOC

ALL LOCS
A & S
A - WARD
DISCHARGE
DENTAL
G - WARD
IN-TRANSIT
I - WARD
OR - 1
OR - 2

ADMIT NEW PATIENT

SELECT EXISTING PATIENT

EDIT LIST

REFRESH PATIENT LIST

PATIENT LOCATION MAP

EXIT MEDTAB PROGRAM

Figure 1. Example of patient list screen.

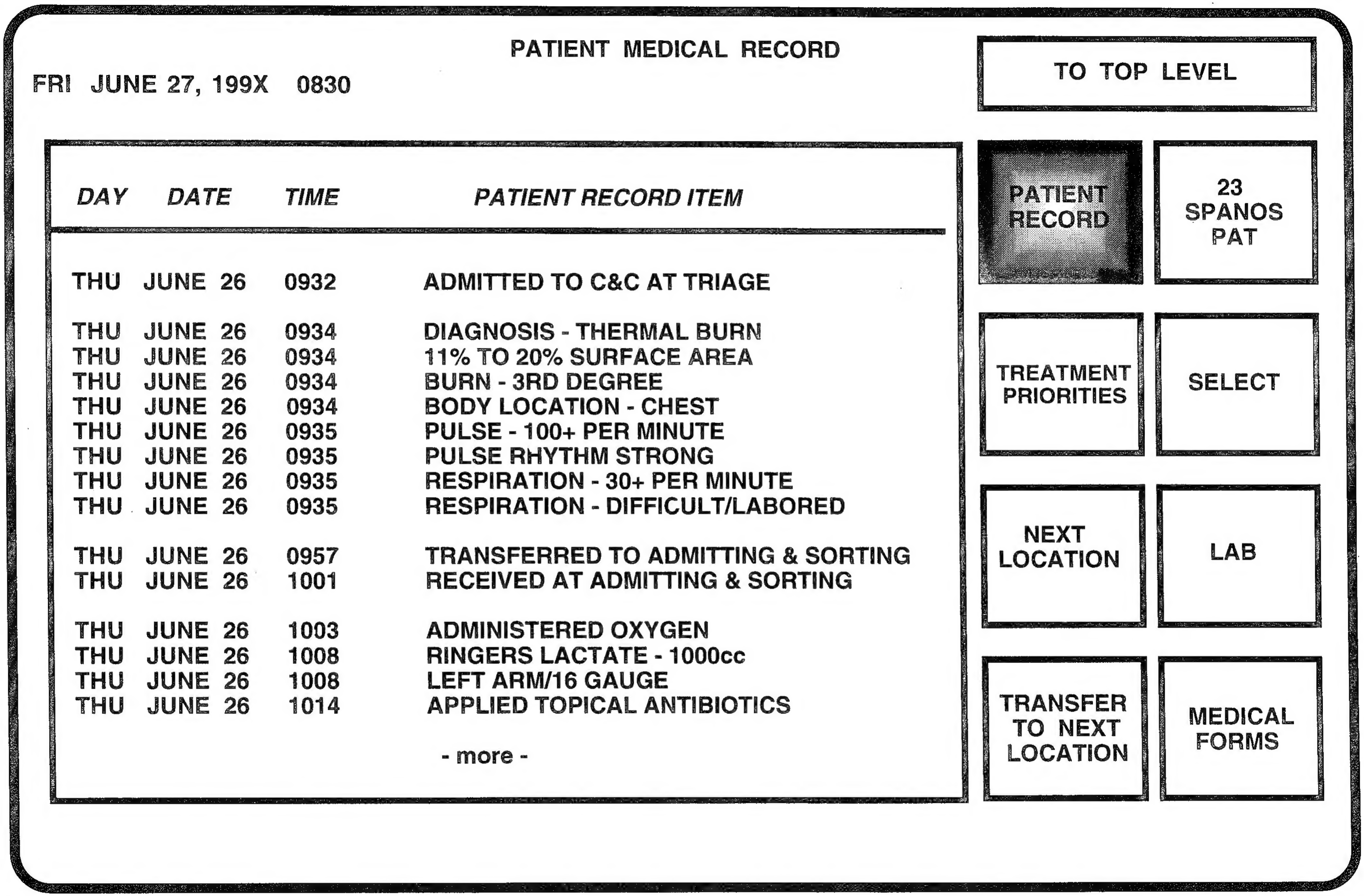

Figure 2. Example of a patient medical record screen.

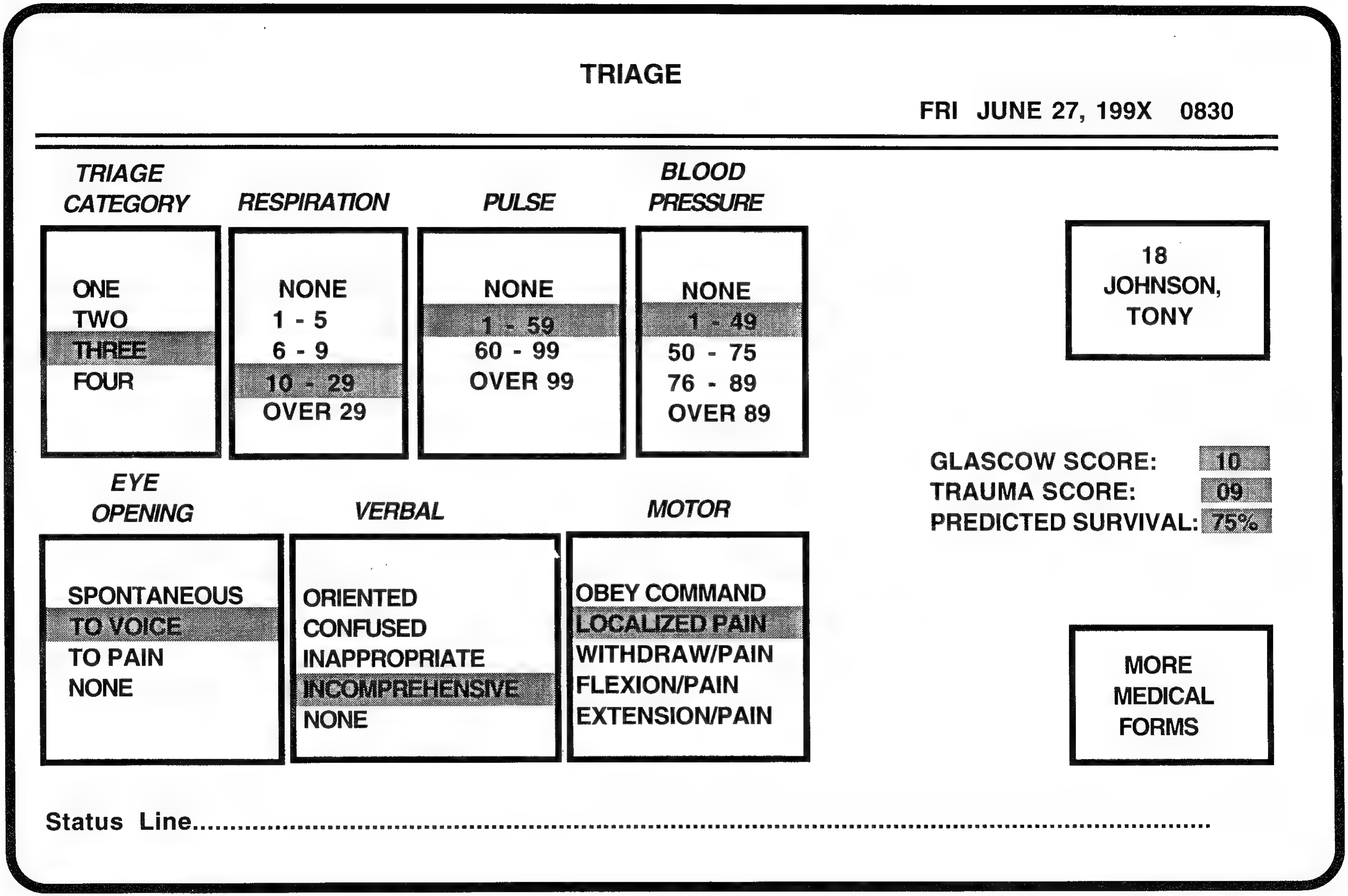

Figure 3. Example of a patient medical data input screen (triage).

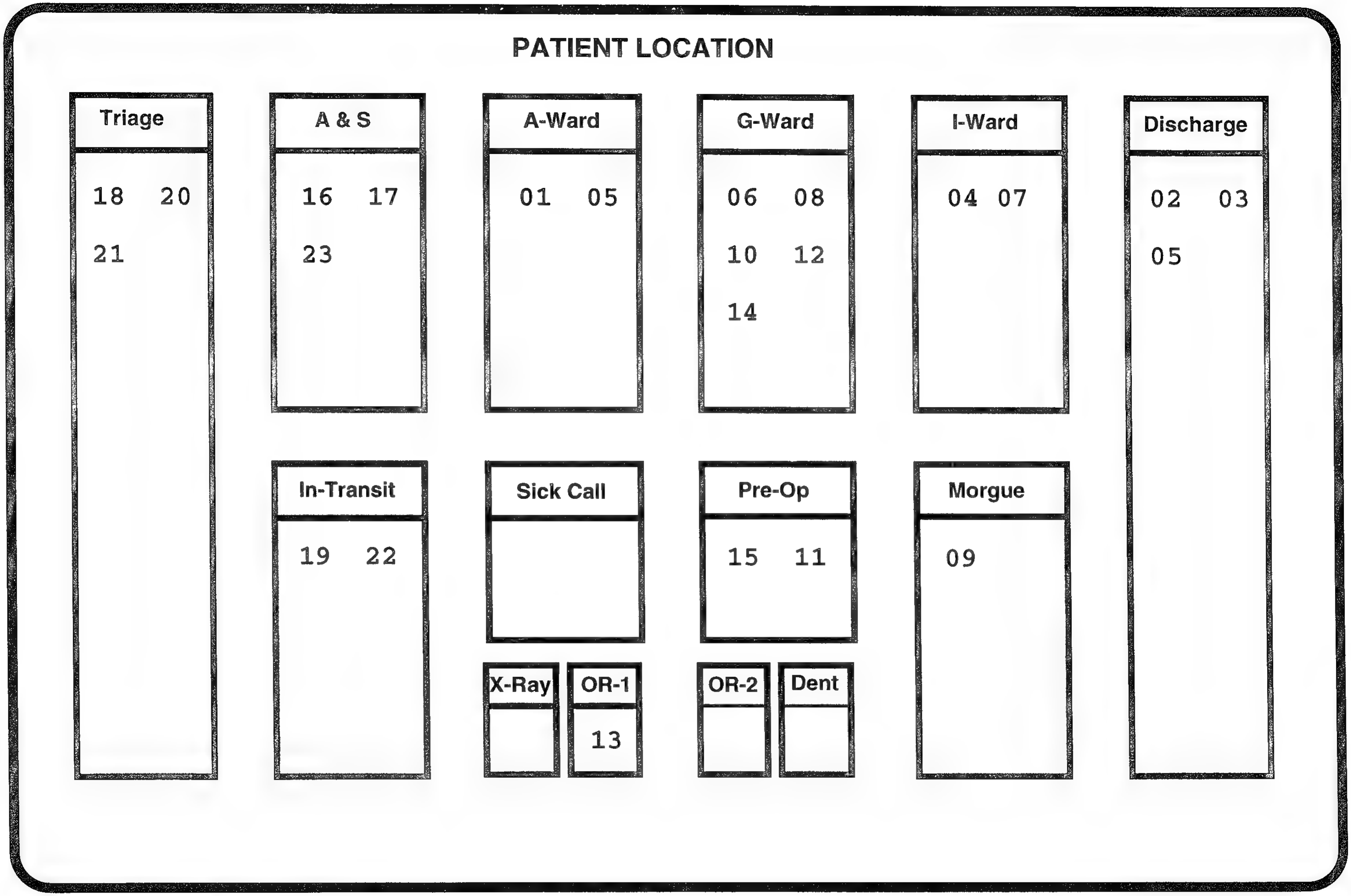

Figure 4. Medical Operations Center (MOC) patient location screen.

initial injury. Further capabilities included the ability to set patient movement priorities, such as the patient queue for x-ray or OR, and the ability to edit patient records and generate facility reports in support of blood management, patient administration, patient evacuation, medical regulating, and logistics, command and control.

Measures

The patient tracking effectiveness of the current manual system and the MEDTRAK system was assessed. Three separate measures of patient location were collected. These included patient location information maintained by the current manual system (MOC status board), patient location information maintained by the MEDTRAK system, and a measure of the observed location of each patient in the facility, which served as the criterion value.

Manual system patient location log. In the current manual system, patient location data were maintained on a large status board positioned in the MOC. This board served as the ongoing record of information required for various reports as specified in the Task Force Medical Regulating Manual (1990). The board was covered with a transparent material that allowed entries to be marked with a grease pencil. Each time the MOC approved a request to transfer a patient to another location within the MTF, the status board was updated to reflect the new location. For example, if a request to move patient 18 from triage to A&S was approved, MOC personnel would erase the check mark from row 18 under the column labeled triage and place it in row 18 under the column labeled A&S.

A researcher stationed in the MOC maintained a copy of the MOC status board on a clipboard. At 10-minute intervals, following the arrival of the first casualty, the researcher made a permanent record of the location of each patient in the facility as it appeared on the MOC status board. These records served as the manual system patient location log.

MEDTRAK system patient location log. The MEDTRAK PC in the MOC monitored the position of each patient within the MTF by logging the information transmitted via R/F modems from the PCs located in the treatment areas. An internal software function was written into the MEDTRAK program that allowed a user to make a permanent electronic record of each patient's location at any time during the exercise. To activate this function the user depressed a single function key that was re-mapped to initiate this program.

The researcher stationed in MOC maintained this record-keeping function in tandem with the status board record-keeping function. At 10-minute intervals, following the arrival of the first casualty, the researcher activated the program, thereby creating a permanent record of each patient's location as reflected by the MEDTRAK system. These electronic records served as the MEDTRAK patient location log.

Observed patient location log. To compare the relative effectiveness of each tracking system, a measure of the observed location of each patient in the facility was required. The researchers stationed in each of the treatment areas were responsible for recording which

patients were present in their location at the specified time intervals. These researchers maintained a clipboard tallied record of each casualty entering or leaving their area. At 10-minute intervals, following the arrival of the first casualty, the researchers in each location would record the patient number of each casualty physically present in their areas, leaving their area, or arriving in their area. These records were used as the measure of actual patient location.

RESULTS AND DISCUSSION

A total of 18 "snapshots" of patient location were recorded during the course of the exercise. The number of patients under the ministration of the MTF during each of the 18 measurements ranged from a low of 3 to a high of 20, with an average of 10 patients accountable per measurement. This yielded a total of 181 sets of observations regarding patient location.

The patient location logs maintained by each of the two systems were compared to the criterion value (i.e., observed location of patients) to determine the number of patient location errors committed by each tracking system. Out of the 181 sets of observations recorded, 37 total patient tracking errors were recorded by the manual system. This compared to 14 errors recorded by the MEDTRAK system. A McNemar's test of symmetry was conducted to determine if the difference in the proportion of errors committed by each of the systems was statistically significant (Rosner, 1986). The results, presented in Table 1, show that the MEDTRAK system recorded significantly fewer patient tracking errors (14) than the current manual system (37) ($\chi^2 = 11.26$, df = 1, $p < .001$).

Table 1

MEDTRAK and MOC Observed Cell Frequencies

	MEDTRAK error	MEDTRAK correct	Total
MOC error	02	35	37
MOC correct	12	132	144
Total	14	167	181

During the course of the evaluation, it became apparent that more than one type of patient tracking error was occurring. Furthermore, it appeared that some errors were more detrimental to the operation of the MTF than were others. Upon examination of the data, three types of tracking errors, each with its own cause and effect, emerged. Table 2 identifies

the error types and presents the frequency with which each error occurred for both the manual system and the MEDTRAK system.

Table 2

Sources of Patient Tracking Errors

	SYSTEM CHAR -ACTERISTIC Location ID Pending	SYSTEM INACCURACY Location Unknown	SYSTEM FAILURE Patient Unknown	Total
MOC	09	15	13	37
MEDTRAK	10	04	0	14
Total	19	19	13	51

The first type of error was found to result from a characteristic inherent in both of the tracking systems. Because neither of the systems were real-time approaches to tracking, some of the errors in identifying patient location were attributed to the tracking function being either slightly ahead of or slightly behind the actual movement of the patients. In the case of the current manual MOC method, a patient's new location was always recorded slightly ahead of the actual movement of the patient. This occurred because the medical provider responsible for sending the patient to the next location notified MOC of the patient's pending change of location prior to the actual transfer of the patient. The MOC status board would then be changed to reflect the pending location of the patient. Patients under the direction of the manual system were only transferred upon notification and approval of MOC personnel. This characteristic produced 9 of the 37 total errors observed in the manual patient tracking system. A similar effect was observed in the MEDTRAK system, however, the direction of the effect was reversed. In the MEDTRAK system, a slight delay occurred between the time the patient arrived in a new location and the time the change was recorded. This type of error occurred because the MEDTRAK system required the patient to be physically present in his new location before the medical provider could record the event on the patient's PC (i.e., by pressing the electronic "patient received" button). This effect accounted for 10 of the 14 errors recorded by the MEDTRAK system. In both cases, these types of errors exerted a minimal effect upon the operation of the MTF because they were both temporary and self-correcting. Furthermore, the exact location of the patients could have been deduced by examining their previous location in the case of the manual system or their pending location in the case of the MEDTRAK system.

The second type of tracking error identified could not be attributed to an inherent characteristic of either tracking system. This type of error occurred when a patient's location was unknown and could not be deduced from information available from the tracking systems. During the course of the exercise, the manual system lost track of 15 patients compared to 4 patients for the MEDTRAK system. This type of tracking error is more serious because it can impair the quality of care administered by the facility. When the patient-monitoring function begins to break down, it affects the execution of other more critical functions, such as the setting of patient treatment priorities and the allocation and utilization of medical resources. For example, under mass casualty conditions, accurate, timely information on resource availability, such as OR and x-ray, promotes more efficient cycling of patients through the treatment process.

A third classification of patient tracking errors was also evidenced during the course of the evaluation. Under the manual system, 13 patients entered the MTF and had progressed through the recovery wards before their presence at the MTF became known to the MOC. Three of these patients who had progressed through the entire treatment system never became known to the MOC. The automatic patient admission feature of MEDTRAK averted all errors of this type. The impact of these types of errors can extend beyond the operation of the MTF alone. Because accurate accounting of patient loads and injury severity are critical to effective medical regulating and theater evacuation policy, failure to adequately carry out this function adversely impacts the operation of the entire medical chain of evacuation.

CONCLUSIONS

Evaluation of the MEDTRAK prototype demonstrated that automation of the patient tracking function at second echelon MTFs improves the effectiveness of patient accounting procedures. The MEDTRAK system provided automatic, error-free patient admission procedures that eliminated the time and personnel previously dedicated to recording and maintaining patient log books. Furthermore, the MEDTRAK system allowed patient admission to be conducted at any time during the patient's stay at the facility. Because of this flexibility, the administrative system can more quickly recover from mass-casualty situations, which have temporarily overwhelmed the ability of facility personnel to manage the information needs of the casualty flow.

Manually initiated communications regarding patient transfers and resource utilization, such as x-ray and OR availability, were replaced with the MEDTRAK automated RF system. This reduced the burden carried by the telephone communication system and freed up medical personnel previously dedicated to act as message runners. Furthermore, in the event the RF network experienced an interruption in service, patient data collection could continue on the patient's battery-powered PCs with no loss of information. Once network communications resumed, all data accumulated during the interim would be automatically routed to their appropriate destination.

Significant improvement in the accuracy of the tracking function was also realized by the MEDTRAK system. For example, during the course of the exercise, 28 patients were either lost or completely unknown to the manual system. In contrast, this situation occurred only four times in the MEDTRAK system, and at no time was any patient unknown to the system. Because of the automatic admission feature of MEDTRAK, all patients physically present at the MTF could, at any time, be accurately identified. The MEDTRAK errors that did occur tended to be less severe in terms of their impact on MTF operations. Thus, while the error rates related to the "system characteristic" inherent in both of the tracking systems was equally split between the two systems (9 for the manual and 10 for MEDTRAK), the impact of this type of error on the operation of the MTF is minor.

These improvements in patient accounting demonstrated by MEDTRAK occurred because the patient administration function provided for the rapid and accurate collection of medical information throughout the exercise. Rapid and accurate patient accounting information is essential to effectively managing theater evacuation policy. The theater Medical Regulating Control Center coordinates medical regulating by processing up-to-date information on MTF patient status and medical capabilities, such as casualty loads, bed availability, and blood status (Task Force Medical Regulating Manual, 1990). Because patient tracking accountability directly affects theater evacuation performance, these expected improvements derived from the use of the MEDTRAK system should, in turn, increase the overall effectiveness of theater combat casualty care.

Another benefit of the MEDTRAK system was the substantial reduction in the number of personnel required to manage the tracking function. In the current manual system, a number of trained medical personnel are required to administer the casualty tracking function. To effectively manage this function, personnel must be dedicated to maintaining log books, patient admission and discharge procedures, telephone and runner communications, status boards, and report generation. Because the MEDTRAK system handles each of these functions automatically, personnel previously assigned to managing administrative requirements may be reallocated to perform the primary medical mission of the facility.

Future Directions

Based upon the results from the current study, the MEDTRAK prototype could be modified to give the system the ability to play a significantly larger role managing the information processing requirements of forward MTFs. Currently, the feasibility of developing dynamic medical supply models, which use actual casualty flow data to determine re-supply requirements in theater, are under investigation. To produce the appropriate re-supply mix, the models will be dependent upon the continuous input of timely casualty flow data. Because MEDTRAK continuously collects medical data on patient PCs, the required data elements could be extracted from the casualty care medical records assembled by the system. Operated in this manner, this secondary function would be transparent to the user and performed as another automated process of the MEDTRAK system.

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13. ABSTRACT *(Maximum 200 words)*

An automated, prototype patient tracking system, designed for a forward Medical Treatment Facility (MTF), was developed and tested. The system, named MEDTRAK, was tested in a side-by-side comparative evaluation with the current manual method of patient tracking. Results of the evaluation showed that the MEDTRAK system admitted, identified, and tracked patients within the MTF significantly more accurately than the current manual system. Furthermore, the types of tracking errors produced by the manual system were found to be more detrimental to both the effective operation of the MTF and to the discharge of theater evacuation policy, than those produced by MEDTRAK. In addition to improved patient accountability, the MEDTRAK system reduced the administrative burden patient tracking placed upon medical personnel thereby, allowing them to perform clinical duties.

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